Concepts of Musculoskeletal Trauma Management

First Edition

AUTHORS AND THEIR DEDICATIONS

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Dedicated to my parents Shanti Tuli and Ram Lal Tuli, my Parents; my teachersProf. K.S Grewal, Prof P. K Duraiswamiand Prof. Balu Sankaran my teachers; and large number of my stimulating students, and my ungrudging patients, who provided me the opportunities to study and enjoy the science and art of Medicine.

Prof. Dr. Sudhir Kumar

Dedicated to my students and patients.

Prof. Dr. Anil Dhal

Dedicated to 'The art of clinical examination from the masters of yesterday to the torchbearers of tomorrow.' The lines on coverpage are thoughtfully written by Prof. Dr. Anil Dhal.

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Dedicated to my patients.

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Dr. Amite Pankaj Agarwal

I dedicate my work to my patients.

Dr. Apurv Mehra

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Section 1

General Principles

1.1 Chapter

Biology of Fracture Healing

One should know the types of bone healing- primary and secondary healing and how it happens

Endochondral ossification and intramembranous ossification

- These are the two methods of bone formation
- Endochondral ossification has a cartilaginous phase before getting converted into the osteogenic phase. This is seen in development of most of the long bones and in fractures which attempt to heal with relative stability or secondary healing. The endochondral ossification has an anabolic phase where there is increase in chondroblasts and a catabolic phase when there is increased activity of osteoclasts and osteoblasts.
- Membranous ossification does not have a cartilaginous phase and hence skips the stage of soft callus. This is seen in development of flat bones and also fractures that attempt to heal with primary healing or absolute stability. Remember that this healing occurs as result of cutting cone action by the osteoclasts and the osteoblasts lay new bone in this cone.

Fracture healing stages

When a bone fractures there is stripping of the periosteum and the vessels

This leads to bleeding at the fracture site and causes hematoma formation

If the fracture is not reduced the hematoma remains and if is immobilized the hematoma causes inflammation and this leads to exposure of the hematoma to progenitor cells.

This helps in the formation of cartilage cells in this hematoma and it is called the soft callus

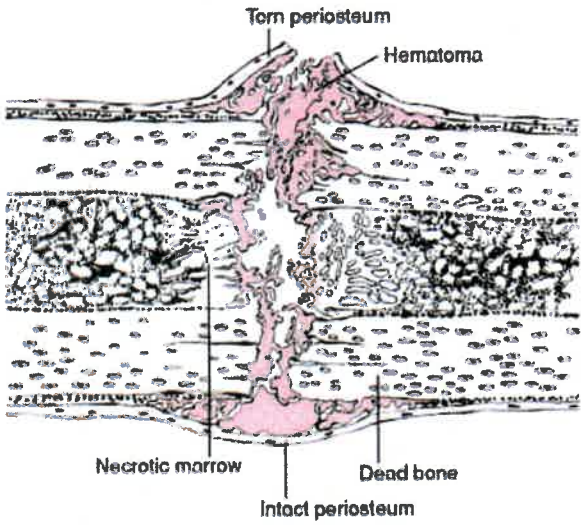
So the stages of healing are

1. Stage of hematoma
2. Stage of inflammation
3. Stage of soft callus
4. Stage of hard callus
5. Stage of remodeling

Stage of hematoma and inflammation:

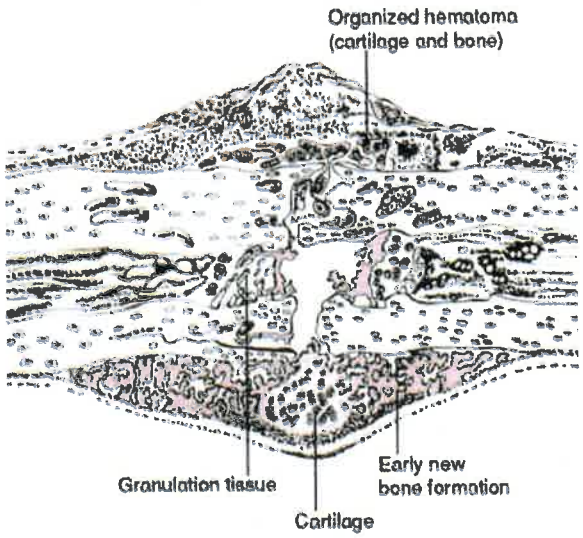
At the time of fracture the following happen-

- The periosteum ruptures
- The blood vessels rupture
- The marrow close to the fracture site becomes necrotic
- The fracture site bone becomes dead
- There is hematoma below the periosteum and the fracture site
- This initiates an inflammatory response and there is increased in many mediator cells and chemicals in this fracture site.
- There is a complex interaction of inflammatory signals, modulators, and cellular components.
- Neutrophils are the earliest and most active cell populations and they remove the debris through their phagocytic mechanism.
- Inflammatory cytokines increase in concentration in early phases, including IL-1β, IL-6, IL-8, IFNγ, and TNFα
- It is always the progenitor cells that help in healing than the already existing mature cells.
- The healing of bone is different from that of any other tissue as the populations of cells that appear in the fracture site and the time at which each individual population appears is important in the final outcome of the union
- Depletion of macrophages or macrophage receptors in the fracture hematoma has deleterious effects on the healing process.
- Initially granulocytes, monocytes, hematopoietic stem cells, and lymphocytes are seen
- Once the above B cell population regress then there is activation of T- cell population in the fracture site
- The periosteum has an inner and an outer layer. The inner layer has periosteal progenitor cells are located
- This is also a source of fibroblasts, osteoblasts, chondrocytes, and a vascular network.
- The periosteum provides an early source of osteoblasts and mesenchymal cells that can directly contribute to calcium deposition and bone formation.
- The periosteal vascular network is responsible for approximately one-third of the cortical blood supply.



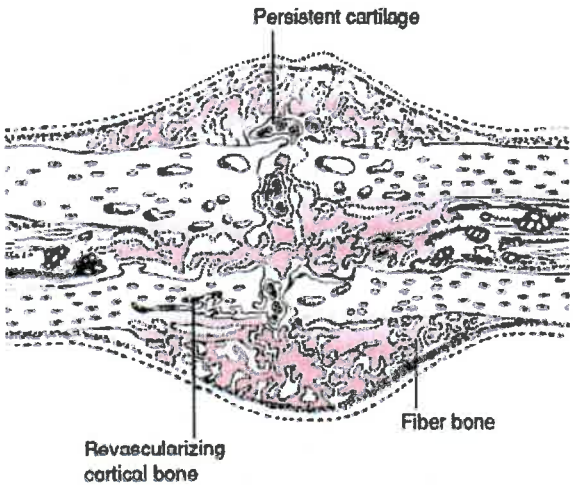
Stage of soft callus

- The mesenchymal cells are derived from the marrow, the endosteal layer of the cortex and peripheral blood. Another potential source of progenitor cells are the pericytes. And are a local cell population that resides in the perivascular space.
- The hematoma when exposed to the inflammatory cells and Sox transcription factor there is formation of chondrocytes which lay down cartilage. Remember Sox9 helps in hypertrophy of the chondrocytes and these remain beneath the periosteum and gets mobilized early once the fracture occurs.
- This chondral deposition is regulated by the TGF -beta and hedgehog signaling
- The chondrocytes get hypertrophied and later undergoes apoptosis and get converted into osteoblasts.



Stage of hard callus

- Osteoblasts lay down calcium and osteoid to transition from soft to hard callus
- These osteoblasts lay done new bone formation
- However due to the high catabolic activity there is osteoclastic activity as well which helps in remodeling



Stage of remodeling

- Osteoclasts help in the remodeling providing the normal shape of the bone
- These cells derive from the hematopoietic cell lineage found on the bone surface and form pits in the surface called Howship lacunae
- This activity is the reason why the bone tissue heals without any scarring

FACTORS AFFECTING FRACTURE HEALING

Internal factors

Blood supply

- Initially the blood flow decreases with vascular disruption
- After few hours to days, the blood flow increases
  - This peaks at 2 weeks and normalizes at 3-5 months
- Un-reamed nails maintain the endosteal blood supply
  - Reaming compromises of the inner 50-80% of the cortex
  - Looser fitting nails allow quicker reperfusion of the endosteal blood supply versus canal filling nails

Head injury may increase osteogenic response

Mechanical factors

- Bony soft tissue attachments
- Mechanical stability/strain
- Location of injury
- Degree of bone loss
- Pattern (segmental or fractures with butterfly fragments)
  - Increased risk of nonunion likely secondary to compromise of the blood supply to the intercalary segment

External factors

Low Intensity Pulsed Ultrasound (LIPUS)

- Exact mechanism for enhancement of fracture healing is not clear

- Alteration of protein expression
- Elevation of vascularity
- Development of mechanical strain gradient

- Accelerates fracture healing and increases mechanical strength of callus (including torque and stiffness)
  - The beneficial ultrasound signal is 30 mW/cm2 pulsed-wave
- Healing rates for delayed unions/non-unions has been reported to be close to 80%

Bone stimulators

- Four main delivery modes of electrical stimulation
  - Direct current
    - Decrease osteoclast activity and increase osteoblast activity by reducing oxygen concentration and increasing local tissue pH
  - Capacitively coupled electrical fields (alternating current, AC)
    - Affect synthesis of cAMP, collagen and calcification of cartilage
  - Pulsed electromagnetic fields
    - Cause calcification of fibrocartilage
  - Combined magnetic fields
- They lead to elevated concentrations of TGF-Beta and BMP

COX-2

- Promotes fracture healing by causing mesenchymal stem cells to differentiate into osteoblasts

Radiation (high dose)

- Long term changes within the remodelling systems
- Cellularity is diminished
  - Patient factors

Diet

- Nutritional deficiencies
  - Vitamin D and calcium
  - Protein malnourishment decreases fracture callus strength
  - Amino acid supplementation increases muscle protein content and fracture callus mineralization
- Gastric bypass patients
  - Calcium absorption is affected because of duodenal bypass with Roux-en-Y procedure
    - Leads to decreased Ca/Vit D levels, hyperparathyroidism (secondary) & increased Ca resorption from bone
  - Treat these patients with Ca/Vit D supplementation
  - Gastric banding does not lead to these abnormalities because the duodenum is not bypassed

Diabetes mellitus

- Affects the repair and remodelling of bone
  - Decreased cellularity of the fracture callus
  - Delayed enchondral ossification
  - Diminished strength of the fracture callus
- Fracture healing takes 1.6 times longer in diabetic patients versus non-diabetic patients

SMOKING

- Decreases rate of fracture healing
- Inhibits growth of new blood vessels as bone is remodelled
- Increase risk of non-union (increases risk of pseudoarthrosis in spine fusion by 500%)
- Decreased strength of fracture callus
- Smokers can take APPROXIMATELY 70% longer to heal open tibial shaft fractures versus non-smokers

HIV

- Higher prevalence of fragility fractures with associated delayed healing
- Contributing factors
  - Anti-retroviral medication
  - Poor intraosseous circulation
  - TNF-Alpha deficiency
  - Poor nutritional intake

Medications affecting healing

- Bisphosphonates are recognized as a cause of osteoporotic fractures with long term usage
  - Recent studies demonstrated longer healing times for surgically treated wrist fractures in patients on bisphosphonates
  - Long term usage may be associated with atypical subtrochanteric/ femoral shaft fractures
- Systemic corticosteroids
  - Studies have shown a 6.5% higher rate of intertrochanteric fracture non unions
- NSAIDs
  - Prolonged healing time because of COX enzyme inhibition
- Quinolones
  - Toxic to chondrocytes and diminishes fracture repair

1.2 Chapter

AO Principles of Fracture Management

AO PRINCIPLES OF FRACTURE MANAGEMENT

These are the universal principles to be applied for the management of fractures of any bone. A good functional outcome could be anticipated as long as these principles are followed during the management.

The 4 AO principles of Fracture Management

1. Anatomical / Functional reduction
2. Stable fixation
3. Preservation of blood supply
4. Early mobilization.

Reduction

The reduction must be as anatomical as possible. This is mandatory in articular fractures as any step / gap in articular surface would preclude optimal outcomes. In metaphyseal and diaphyseal regions, a "functional" reduction is good enough in which length, alignment and rotations are maintained. It is not necessary to achieve perfect anatomical reduction of all the fragments in this region as to try to do so, one could cause significant soft tissue damage thereby hampering the biology which is quintessential in the healing of the fractures.

The reduction could be achieved by direct or indirect means. In Direct reduction, the forces / instruments are applied at or near to the fracture site to achieve realignment. In indirect reduction, the forces are imparted along the axis of the limb and using the action of soft tissues to achieve reduction.

System	Advantages	Disadvantages
Direct reduction	Easy to visualize the reduction Easy to reduce the fracture	Increases soft tissue insult
Indirect reduction	Difficult to visualize and reduce the fracture More ionizing radiation exposure as judgement for reduction is based on Carm	Preserves soft tissue biology.
Examples	Reduction clamps Pointed instruments K wires	Traction (Manual / fracture table) External fixator Charnleys distractor

Stable Fixation

Stability means that the fracture does not visibly displace under physiological load. It means that once the fracture is stabilized adequately with external / internal device, the limb can withstand physiological loading and the rehabilitation could be started early.

The degree of stability determines the type of fracture healing. There are 2 types of stability that can be achieved with fixation. Absolute and relative stability.

Characteristics	Absolute Stability	Relative stability
Definition	No motion at fracture site under physiological loading	Some micromotion occurs at fracture site under physiological loading
Location where desired	Articular fractures	Metadiaphyseal fractures
Type of fracture pattern	Simple / Wedge	Comminuted
Type of bone healing	No callus	With callus
Also known as	Primary bone healing	Secondary bone healing
Prerequisite	Contact between fractured ends	No need of direct contact and some gap is tolerated
Type of reduction	Requires anatomical reduction	Anatomical / Functional reduction
Means to achieve	Lag screw, compression plating, buttress plating, Tension Band wiring	All other methods Nailing, cast, external fixator, Bridge plating

Preservation of blood supply

It must not be forgotten that the bone is a living tissue with its root in the soft tissues thereby deriving the blood supply. Extensive stripping of periosteum / soft tissue mishandling could lead to devitalized bone leading to necrosis and infection. So a surgeon must be very careful during dissection, respecting the muscular planes and preserving as much as soft tissues around the bone as possible. Percutaneous techniques, indirect reduction techniques, minimally invasive surgeries are all towards preserving the biology.

Early mobilisation

A patient undergoing a surgery and then immobilised for a long time is bound to have stiff joints and poor functional outcome no matter how well the surgery was performed. The most important aspect of any surgery is how well the patient rehabilitates and hence essential that the neighbouring joints are mobilised early after surgery to prevent stiffness.

1.3 Chapter

AO Classification (Old Vs New)

AO described the classification system of long bone fractures in 1987 and from then have incorporated the fractures of spine and flat bones and other regions too (pelvis, skull hand, foot), thereby making it a comprehensive system which can be used to describe any fracture pattern in any part of the human body.

Uses of the AO system

1. Universal comprehensive system
2. Less intra and inter observer variability
3. Can be used to prognosticate injury pattern
4. Alphanumerical code useful to store data in the ICD classification of patient details.

The "Four Box" concept

The classification system is alphanumerical and is described within 4 boxes.

1st box – describes which bone is injured

2nd box – which region of the bone is injured (proximal, middle or distal part)

3rd box – describes type of fracture

4th box – further describes the type of fracture

1st box

All the different bones have been assigned a numerical value.

- Humerus – 1
- Forearm bones – 2
- Femur – 3
- Leg bones – 4
- Spine – 5
- Pelvis – 6
- Hand – 7
- Foot – 8
- To note
  - Scapula – 14
  - Clavicle – 15
  - Patella – 34
  - Malleolus – 44

2nd box

The proximal and distal regions of the bone are given nos. 1 & 3 respectively. The middle diaphyseal segment is given no. 2.

How to define the proximal & distal region of a bone. It is done by following the "square" rule. A square is drawn with the maximum breadth of the bone as the breadth of the square. The region within the "square" is considered epi-metaphyseal and given nos. 1 or 3 depending on whether it lies in the proximal part of the bone or distal respectively.

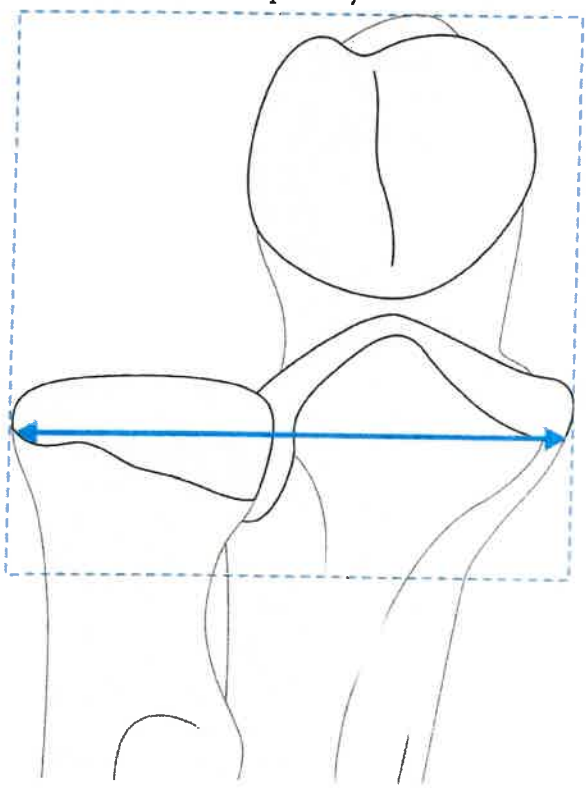


Fig. 1: diagram depicting the proximal region of the area by drawing a square with the maximum width of the bone.

3rd box

The 3rd box encompasses the description of the type of fracture and is an alphabet A, B or C. The description depends on whether the fracture lies within the diaphyseal segment of the bone or proximal / distal region of the bone.

For diaphyseal fractures,

- A – simple fracture
- B – wedge fracture
- C – comminuted fracture

For proximal / distal regions,

- A – extraarticular fracture
- B – partial articular fracture
- C – intraarticular fracture

4th Box

This further describes the pattern of fractures. It is either 1, 2 or 3.

For A type diaphyseal fractures,

- 1 – spiral (long oblique)
- 2 – oblique (short oblique)
- 3 – transverse

For B type Diaphyseal fractures,

- 1 – simple wedge
- 2 – bending wedge
- 3 – comminuted wedge

For C type Diaphyseal fractures,

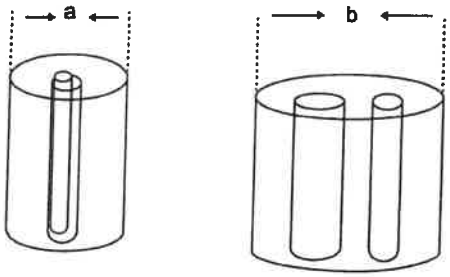
- 1 – complex spiral
- 2 – segmental
- 3 – complex irregular

The New/ modified AO Classification (2018)

In 2018, the new / modified classification system was described which made changes to the existent system and tried to incorporate various other classification system into its own system thus making it more comprehensive.

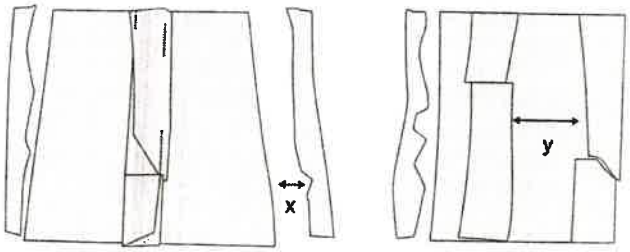
The notable changes to the old system are:

1. Radius and ulna given separate number 2R & 2U respectively
2. Tibia fractures are given number 4 (as before), but fibula fractures are described with number 4F
3. In diaphyseal fractures, B1 & C1 fractures have been deleted. B2 denotes simple wedge & B3 denoted comminuted wedge. C2 denotes segmental fracture & C3 denotes comminuted fracture.



Padding Index (x/y)

- Described bybhatia and Housden → 2006
- Is the ratio of padding thickness in the plane of maximum deformity correction (x) and the greatest interosseous distance (y) in AP view.
- "x" is the padding thickness under the molded cast in lateral view in the planeof maximum deformity correction
- "y" is the maximum interosseous distance in the AP view
- Padding index must be < 0.3
- If there is an over-padded cast → then the value of "x" will increase → overall value of x/y → increase → loss of 3-point fixation of the fracture, as there would be a greater "play" between the plaster cast and the bone



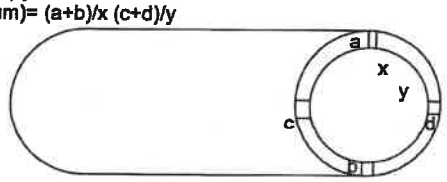
Canterbury Index

- Described bybhatia and Housden→ 2006
- It is the sum of cast index and padding index.
- If the sum is > 1.1 then the risk of redisplacment is high

Gap index

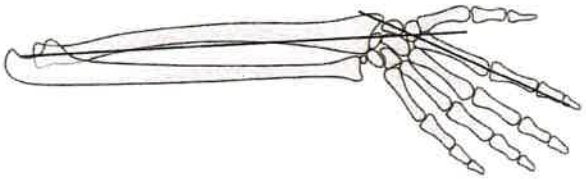
- Radiographic measurement by Malviya et al
- Ratios of the gaps in the cast at the level of the fracture to the entire inside width of the cast in two planes

Gap index- Lat view = (a+b)/x
AP view = (c+d)/y
Gap index (Sum)= (a+b)/x (c+d)/y



Second metacarpal-radius angle(2007)

- It is the angle between the second metacarpal and the long axis of the radius in the anterioposterior plane
- It represents the deviation (radial/ulnar) of a moulded cast.
- The greater the ulnar deviation →, the more likely the success of the initial cast.
- An ideal outcome if angles >0° (ulnar moulded)
- This is important for most dorsally displaced fractures



Three point index(2008)

- It is calculated by dividing the sum of three critical gaps seen on an anteroposterior radiograph by the transverse projection of the contact area of the fracture fragments ([a + b + c]/x) and by dividing the sum of three critical gaps seen on a true lateral radiograph by the sagittal projection of the contact area of the fracture fragments ([d + e + f]/y) .
- The critical gaps were selected on the basis of the most important points in the cast that maintain the reduction against the common displacement forces.

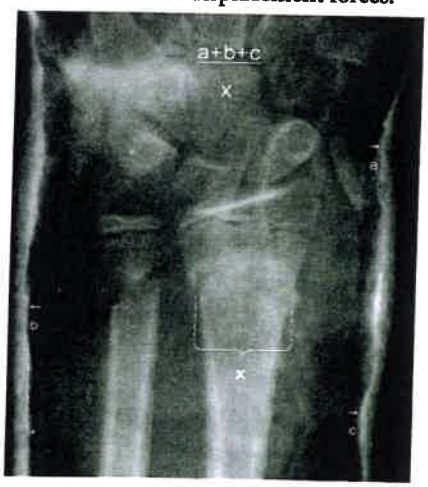


Fig: a" and "c" are the distal and proximal radial gaps, and "b" is the ulnar-side gap at the level of the fracture. "a" is the narrowest gap around the radiocarpal or proximal carpal joint, "b" is the narrowest gap within 1 cm of the fracture line on the ulnar side, and "c" is the narrowest gap on the radial side about 3 to 5 cm proximal to the fracture site. "x" is the projection of the contact length between the proximal and distal fragments in the horizontal plane on the anteroposterior radiograph.

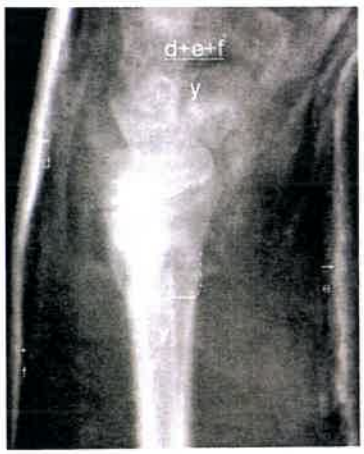


Fig: 'd" and "f" are the distal and proximal dorsal gaps and "e" is the volar gap at the level of the fracture. "d" is the narrowest gap around the radiocarpal or proximal carpal joint, "e" is the narrowest gap within 1 cm of the fracture line on the volar side, and "f" is the narrowest gap on the dorsal side within 3 to 5 cm of the fracture site. "y" is the projection of the contact length between the proximal and distal fragments in the sagittal plane on the lateral radiograph.

Summary

- Redisplacement of a fracture can be predicted if
  - Cast index > 0.8
  - Padding index > 0.3
  - Canterbury Index > 1.1.
  - Gap index > 0.15
  - Second-metacarpal-radius angle < 0degree
  - Three point index> 0.8

PAIN MANAGEMENT IN ORTHOPEDIC PATIENT

Definition

Pain is a unique subjective experience of an individual, which cannot be adequately defined, identified, or measured by an observer.

Components

- Sensory component describes the quality, quantity and geography of area involved in pain.
- The motivational-affective component explains the individuals approach to the pain
- Cognitive component decides that how much pain that individual is going to feel depending upon past experiences and modulations done by central and peripheral nervous system.

Pain Threshold

It is defined at the point at which any stimulus is felt as pain. Aging increases the pain threshold and this change may be due to changes in the thickness of the skin or peripheral neuropathies.

Perceptual Dominance

It is the phenomenon when increase in the pain threshold occurs at one point (part of body) due to severe pain in another point (part of body).

Pain Tolerance

It is an intensity of pain that an individual will tolerate before any visible responses.

Types of Pain

- Somatogenic pain is localized in the body tissue, if causes are inflammatory it is called nociceptive pain and if pain is secondary to sensitization of nervous system (peripheral or central), it is called neuropathic pain.
- Psychogenic pain is pain for which there is no known physical cause but processing of sensitive information in central nervous system (CNS) is disturbed.

Acute and Chronic Pain

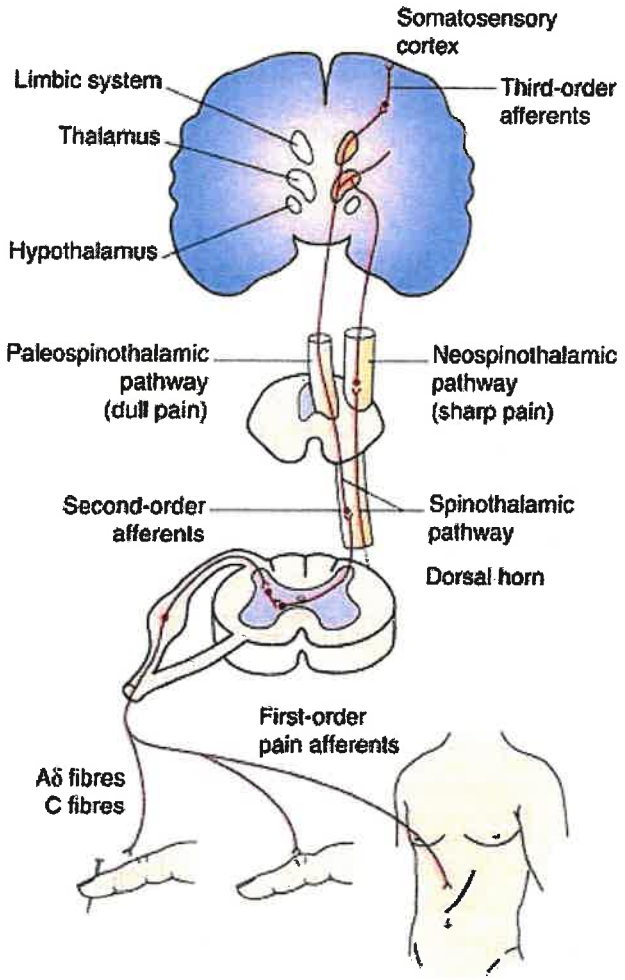
Table: Difference between acute and chronic pain

Characteristics	Acute Pain	Chronic Pain
Temporal features	Short history of onset and does not last longer than days or weeks	Long history with often poorly-defined onset, duration unknown
Intensity	Variable	Variable
Associated effects	If pain is severe anxiety may be prominent and sometime instability	Depression and instability is prominent feature
Associated pain behaviors	When pain is severe pain behaviors (e.g., moaning, rubbing and splinting) may be prominent feaures	Specific behavior may or may not be present. If pain is severe and for long duration specific behaviors (e.g., assuming a comfortable position) may occur
Other associated features	Features of sympathetic hyperactivity when pain is severe (e.g, tachycardia, hypertension, sweating, mydriasis)	Usually have one or more vegetative signs such as lassitude, anorexia, weight loss, insomnia, loss of libido. Sometimes these signs may be difficult to distinguish from other disease-related effects

Types of acute pain

1. Somatic :Pain arising from the skin or close to the surface of the body is called somatic pain
2. Visceral
   a. Localized: if it arising from internal organs, abdomen, or chest is visceral pain.
   b. If pain is felt away from its origin is known as referred pain.
   i. Mechanism
   - The area of origin of pain and referred area are supplied by the nerves from the same spinal segment or convergence of impulses occurs from viscera and skin in the CNS. The suggested mechanism is: an irritable focus is generated at the level of spinal cord where pain signals from viscera enter and these signals further facilitate the afferent impulses from the skin entering at the same segment resulting in cutaneous pain.
   - Sensitization of dorsal horn (DH) neurons.

Pathways of Pain



Gate Control Theory (Pain production and Modulation Theory)

- According to this theory, large A-δ and small C-fibers carry the nociceptive impulses to the spinal cord through and form synapses in SG. The cells in SG regulate transmission of impulses to CNS depending upon other inputs from other areas of spinal segments or brain and function as a gate.
- "Closed gate" is the situation where stimulation of A-α and A-β (larger nerve fibers) causes decreases stimulation of T-cells (the second afferent neuron) which decreases the transmission of impulses and diminishes pain perception.
- Stimulation of small fiber increases the stimulation of T-cells and inhibits cells in SG. This increased transmission of impulses (open gate) leads to enhance pain perception.
- Other factors in nervous system also influence the functioning of gate control. The CNS may close, partially close, or open the gate through efferent pathways and modulates pain perception. Naturally occurring opioids like endorphins (ED) also affects the transmission through gate. All ED act by attaching to opiate receptors on the plasma membrane of the afferent neuron. This result is inhibition of release of the neurotransmitter, thus blocking the transmission of the painful stimulus.

Disturbances in Pain Perception and Nociception

- Congenital analgesia is a condition when patient does not feel a pain because nociceptive stimuli are not processed and/or integrated at a level of brain.
- Congenital sensory neuropathy is a condition in which peripheral nerves and spinal afferent tracts are unable to transmitted nociceptive stimuli.
- Diseases of parietal lobe of brain, syringomyelia and acquired neuropathy, e.g. Neuropathy in chronic diabetes mellitus.

Postoperative Pain and Its Management

- Postsurgical pain is a complex response to tissue injury during surgery and also due to secondary inflammatory response which initiates hypersensitivity of the CNS.
- Adequate pain control results in better surgical outcome in terms of increased patients satisfaction, early mobilization and shorter hospital stay.

ASSESSMENT OF PAIN

Various methods, i.e. Charts/questionnaire and other tools have been used to quantify the pain in postoperative period.

Pain Assessment Tools

- Numerical rating scales (NRS): The NRS is one of the most convenient ways of determining pain intensity. A 11-point (i.e. 0 = no pain–10 = maximum pain) NRS scale is commonly used.
- Verbal rating scales (VRS): It is another scale which is simple and fast to use. This scale uses verbal response in form of words to assess severity of pain like no pain, mild pain, moderate pain or severe pain.

- Visual analog scales (VAS): VAS is most popular scale for pain assessment. It usually consists of a line labeled at 0 or no pain at one end and 10 or 100 on other end to express extremes of the feeling to be measured.
- Pain measurement by pictures: The pictures are assigned a score and patients are asked to indicate their pain which matches with the expression of a picture.
- Pain assessment by questionnaire:
  a. The Mcgill Pain Questionnaire (MPQ): It is most commonly used questionnaire to assess qualitative and quantitative experience of pain. The MPQ consists of 78 words describing pain in sensory, affective and evaluative terms.
  b. Brief pain inventory (BPI): It includes three items to measure pain, severity and quality. It also includes seven additional items, e.g. Mood, function, sleep, interpersonal relationships which may be interfered or affected by pain.

Systemic effects of poor pain control

- Increased sympathetic response of the body which cause increase in heart rate (tachycardia), cardiac work and oxygen consumption.
- Increased risk of deep vein thrombosis and consequent pulmonary embolism
- Reduced gastrointestinal (GI) tract and urinary tract motility which may lead to postoperative ileus, nausea, vomiting and urinary retention.
- Psychological changes
- Increase in the morbidity and mortality
- Generates negative emotions like anxiety and depression and demoralization.
- Sleep deprivation
- Acute pain if not treated immediately and adequately leads to chronic pain conditions.
- Peripheral sensitization

Strategies for adequate postoperative pain control

- Prevention of central sensitization:
  - Treat acute pain adequately and timely.
  - Use drugs that prevent expression of c-fos. Drugs like opioids, local anesthetics, N-methyl-D-aspartate (NMDA) antagonist and alpha-2 agonists in acute stage to treat pain.
  - Use continuous regional anesthesia in operation and early postoperative period. Combined with tramadol and paracetamol in late postoperative period is a good option to prevent central sensitization.
- Management of central sensitization:
  - If central sensitization develops treat it early.
  - Nonsteroidal anti-inflammatory drugs (nsaids) are not the option to treat it. We should use drugs, which stimulate descending inhibitory systems and NMDA antagonistic actions.
  - Tramadol + Paracetamol ± Tricyclic antidepressants should be ideal to treat central sensitization.

Methods for postoperative pain control

Multimodal Analgesia

The multimodal analgesia is a combination of two or more analgesics, each with a different mode of action to improve analgesia and to decrease side effects through a reduction in doses of analgesics, particularly opioids.

Pre-emptive Analgesia

It is now believed that it requires less analgesic to control pain before it starts than after the noxious input has begun.

Mechanism of Action

The concept of pre-emptive analgesia is to block noxious signals prior to a surgical incision which gives some protection against postoperative pain. Surgical incision results in pain signals and nociceptors activation directly leads to the discharge of neuropeptides such as Neurokinin A, calcitonin gene-related peptide (CGRP), and substance P from peripheral terminals of the primary nerve fibers.

At the same time an inflammatory response is provoked by the release of contents from damaged cells. These two processes contribute to the presence of a "sensitizing soup" of inflammatory mediators that includes bradykinin, serotonin, histamine, nitric oxide, and several others. This leads to repetitive stimulation of small-diameter primary afferent fibers causing "sensitization" or "wind-up" of both peripheral and CNS neurons.. Pre-emptive analgesia decreases postoperative pain by the prevention or attenuation of this wind-up phenomenon.

Methods

Nonsteroidal anti-inflammatory agents (nsaids), opioids, α2 -agonists, and NMDA antagonists such as ketamine and dextromethorphan.

Preventive Analgesia

- Preventive analgesia can be defined as "when postoperative pain and analgesic
- Consumption are reduced relative to another treatment, a placebo treatment, or to no treatment, as long as the effect is observed at a point in time that exceeds the clinical duration of action of the target drug", i.e. 5.5 half-lives).

Locoregional Analgesia for postoperative pain management

- Local Wound Infiltration
- Local infiltration analgesia (LIA) technique involves infiltration of a large volume dilute solution of a long-acting local anesthetic agent at the time of surgery. Adjuvants (e.g. Epinephrine, ketorolac, an opioid) can be mixed with local anesthetic to improve the effect. The duration of analgesia can be prolonged by the placement of a catheter to the surgical site for postoperative administration of further local anesthetic.

Peripheral Nerve Blocks (e.g.adductor canal block)

- Peripheral nerve blocks (PNB) are safe and effective techniques of providing postoperative analgesia that cut down on time to hospital discharge, reduce postoperative pain and improve overall patient satisfaction.
- A catheter can be placed to give intermittent boluses or

continuous infusion of local analgesia to prolong the duration of analgesia.

Epidural Analgesia

- Epidural analgesia has dual advantage that it provided anesthesia during surgery and extended analgesia to postoperative period by means of a catheter
- Combinations of local anesthetic, opioids and other medications (clonidine, tramadol, dexmedetomidine, etc) can be titrated to patient comfort and allow for an acceptable degree of motor function while effective sensory block.

Patient-controlled Analgesia

- Where pain control (drug delivery) is given in the hand of patients [patient-controlled analgesia (PCA)] provides continuous analgesia and leads to higher patient's satisfaction.
- PCA provides pain medication at the patient's need. The intravenous and epidural PCA are commonly used for postoperative pain and represent the philosophy of "patient controlled pain relief but with safety (partly inherent in system and partly provided and controlled by care provider)".
- Intravenous PCA is provided through an electronically controlled infusion pump that delivers an amount of intravenous analgesic when the patient presses a button. PCA protects the patient from overdose of the drug because programing of PCA pumps is such that the PCA will deliver a dose at set intervals only.
- Epidural-patient-controlled epidural analgesia (PCEA): in this technique administration of drugs in epidural space
- Nasal PCA or patient-controlled intranasal analgesia (PCINA): These PCA devices are in a nasal spray form with inbuilt features to control the number of sprays that can be delivered in a fixed time period.
- Transcutaneous PCA: Transcutaneous PCA delivery systems works on the principle of iontophoretic systems.
- These PCA are popular for administration of opioids such as fentanyl, or local anesthetics such as lidocaine.
- "Iontophoretic transdermal system (ITS)" is a drug delivery system which works on the principle of iontophoresis. The drug is absorbed in the tissues by application of low-intensity electrical fields across skin.
- Oral: Self-administration of oral over-the-counter or prescription painkillers by patient may be called as "patient controlled analgesia method"
- Inhalational: historical importance

Advantages of PCA

- Self-administration of pain medication and therefore faster relief from pain because there is no delay between pain and its treatment.
- Less amount of drug is required due to adequate and timely control of pain
- It provides the feeling of self-control, better pain relief with less sedation and enhanced satisfaction.
- Patients can be mobilized early due to less sedation and good pain relief. This results in better respiratory function, less risk of pneumonia and other respiratory complications.
- Reduced length of stay reduces healthcare costs and less chance of nosocomial infections.

Disadvantages

- Possible misuse and abuse of opioid drugs
- Under-dose or overdose of medication if PCA device is not programed properly for the patient.
- If patient has learning difficulties and is confused due to any reason, use of PCA is not advisable.
- Critically ill patients and patients with poor manual dexterity may be unable to press the buttons of PCA pump.
- Patient-controlled analgesia may not be appropriate for younger patients (children of less than 5 years).

Other Limitations

- Patient-controlled analgesia provides excellent pain control; however, there are many factors that may influence this. Lack of education could be an important factor; however, this can be overcome easily by simple training. Myths and misconceptions associated with opioids use among paramedical and medical staff is another limiting factor which needs further education and training of caregivers. Mental incapacity and very young age can also limit its utility.

Alternative nonmedical methods

- Education:
  - Meditation and deep breathing techniques
  - Hypnosis

Drugs used for postoperative pain control three major groups:

(1) Opioids analgesics, (2) Nonopioid analgesic and (3) Adjuvants.

Opioids

- Opioid analgesics are strong analgesic used for moderateto-severe pain in the early postoperative period.
- The opioid system consists of at least three distinct opioid receptors
  - Mu receptors are responsible for mechanical, chemical and thermal nociception at a supraspinal level.
  - Kappa receptors are responsible to modulate spinally mediated thermal nociception and chemical visceral pain.
  - Mechanical nociception and inflammatory pain is modulated by δ receptors.
- According to the nature of affinity to receptors opioid drugs are classified as opioid agonists, partial agonist and agonist antagonist.
- "Opioid agonist" analgesics bind predominantly to the μ receptor. This group includes morphine, meperidine, fentanyl, sufentanyl, alfentanil, remifentanil, hydromorphone, codeine, oxycodone, oxymorphone, hydrocodone, methadone and propoxyphene.

- "Opioid Agonist–Antagonist" analgesics have agonist activity at one receptor and no or low activity on other receptor (antagonist activity). The receptor and drug
- Interaction is very complex for these drugs. Nalbuphine and pentazocine are examples of opioid agonist—antagonist analgesics.
- "Opioid partial-agonist" analgesics bind to an opioid receptor producing a partial agonist response. Buprenorphine is an example of a partial agonist at the μ receptor; however, butorphanol is partial agonist and antagonist at the μ opioid receptor, as well as competitive antagonist and partial agonist at the κ receptor.
- Routes of administration and uses: intravenous/ intramuscular/ subcutaneous, transmucosal/ epidural, intrathecal and transdermal.
- In orthopedic surgical procedures acute pain is managed with systemic opioids; however, once acute postoperative pain is over then controlled-release opioids are an optimal choice for step-down analgesia in the late postoperative and rehabilitation periods.
- The problem with opioid drugs is the variety of perioperative complications, e.g. Drowsiness and sedation, postoperative nausea and vomiting (PONV), pruritus, urinary retention, ileus, constipation and respiratory depression particularly in elderly patients and hence close monitoring is essential.

Tramadol

Nontraditional, centrally acting analgesic because analgesic action of tramadol is due to the combined effects of its two enantiomers and the M1 metabolite. Tramadol is a "weak" opioid analgesic for postoperative pain relief with potency of 10% that of morphine. Like other opioids it does not produce significant constipation or respiratory depression. Unlike opioids it has low abuse potential. However, seizures may cause when doses larger than the recommended are given. Tramadol is available for oral, rectal and parenteral administration.

Nonopioid Analgesics

- Nonsteroidal anti-inflammatory drugs NSAIDs and COX-2 inhibitors
- These drugs are known for their anti-inflammatory and analgesic actions.
- Mechanisms of action of NSAIDs: Prostaglandins are responsible for inflammation and pain which occurs following tissue injury. Nsaids have ability to decrease prostaglandin formation through inhibition of COX pathways. NSAIDs inhibits the production of prostaglandins from arachidonic acid, thus decreases peripheral sensitization and the activation of peripheral nociceptors. Recent evidence has suggested that rapid upregulation of COX-2 expression occurs in the CNS following peripheral trauma leading to central sensitization and pain hypersensitivity.

Indications and routes of administration:

- COX-2-selective inhibitors provide the additional safety by not affecting platelet function which otherwise may result in bleeding during perioperative period.
- Recent practice guidelines for acute pain management have suggested that "unless contraindicated, all patients should receive around-the-clock regimen of nsaids, COX-2 inhibitors, or acetaminophen" during perioperative period.

Concerns and contraindications:

- Nonselective use of NSAID toxicity causes bleeding due to platelet aggregation and
- Gastroduodenal ulcers.
- Rare hepatic toxicity
- Aspirin may induce asthma,
- NSAID should be used with caution in patients of older age group, borderline renal or hematological status or previous dyspeptic symptoms.
- Many selective COX-2-inhibitors like celecoxib and rofecoxib are no longer in use due to adverse cardiovascular events.

Acetaminophen/ Paracetamol

Acetaminophen is a safe antipyretic, analgesic drug with poor anti-inflammatory action. It was available in oral form and was used either preoperatively as pre-emptive analgesic or postoperatively as step-down analgesic.

Adjuvants

Alpha-2 adrenergic agonists

- Dexmedetomidine and clonidine: These are selective α-2 agonist drugs acts through adrenergic receptors present in the spinal cord and locus coeruleus of CNS.
- Dexmedetomidine, a potent α2 adrenoceptor agonist, is approximately eight-times more selective towards the α2 adrenoceptor than clonidine. Both the drugs do not have any inherent analgesic property, however, work as adjuvants to local anesthetic when used in regional and neuraxial anesthesia and also when used with other analgesics parentally.

Ketamine

- Ketamine is an NMDA antagonist. These NMDA receptors are involved in the hyperexcitability of spinal cord nociceptive neurons by C fiber stimulation. Ketamine inhibits voltage-gated sodium and potassium channels and, in addition, the reuptake of serotonin and dopamine.
- However, the possibility of side effects like hallucinations and blurred vision should be kept in mind if large dosage has to be used.

Gabapentin-type drugs

- Gabapentin binds to the α-2 subunit of presynaptic voltage-gated calcium channels of GABA receptors. It works by preventing the release of neurotransmitters responsible for the activation of the pain pathway by preventing the entry of Ca+ into neurons.
- Pregabalin is a derivative of gabapentin and structural analog of GABA, is known to have analgesic, sedative and antianxiety properties.

Glucocorticoids

Dexamethasone: Steroid adjuvants have been found to prolong the block duration when used in regional blocks.